Washington University School of Medicine
Digital Commons@Becker

Independent Studies and Capstones

Program in Audiology and Communication Sciences

2006

Are there hazardous auditory effects of high-frequency turbines and ultrasonic dental scalers on dental professionals?

Susanna Storm Bono

ARE THERE HAZARDOUS AUDITORY EFFECTS OF HIGH-FREQUENCY TURBINES AND ULTRASONIC DENTAL SCALERS ON DENTAL PROFESSIONALS?

by

Susanna Storm Bono

A Capstone Project submitted in partial fulfillment of the requirements for the degree of:

Doctor of Audiology

Washington University School of Medicine
Program in Audiology and Communication Sciences

May 19, 2006

Approved by:
William W. Clark, Ph.D.,
Capstone Project Advisor

Abstract: The purpose of this pilot study was to survey dentists in the St. Louis area to assess their subjective opinion of commonly used dental handpieces as well as history of noise exposure and use of hearing protection. Selected handpieces were then chosen to measure their output levels and determine if emissions are hazardous to the auditory system.

General Introduction

Many individuals are exposed to noise in workplace environments. Although this is true, not all workers are exposed to levels of noise that are hazardous to the auditory system. A simplistic definition of noise is an unwanted sound from any source. It is also described as audible acoustic energy that adversely affects the physiological or psychological well-being of individuals (Kryter, 1985). Generally, noise is not considered hazardous to the auditory system unless it reaches a designated intensity, frequency, and/or duration. At this designated level, the noise becomes hazardous to the auditory system and the exposed individual is considered at-risk for resultant hearing loss.

Occupational noise-induced hearing loss (NIHL) is defined by the American College of Occupational and Environmental Medicine as a "…hearing loss that develops slowly over a long period of time (several years) as the result of exposure to continuous or intermittent loud noise (ACOEM, 2002).

NIHL is considered handicapping once it adversely affects the day-to-day existence of an individual (Retrieved April 1, 2006, from www.entnet.org). This occurs when NIHL degrades speech intelligibility, rendering it difficult to communicate with others within the home and workplace. NIHL can result in both auditory and nonauditory symptoms. Auditory symptoms include social handicap, tinnitus, paracusis, speech misperception, as well as both temporary and permanent threshold shifts, while nonauditory symptoms include physical, emotional, and physiological stress (ASHA, 1991).

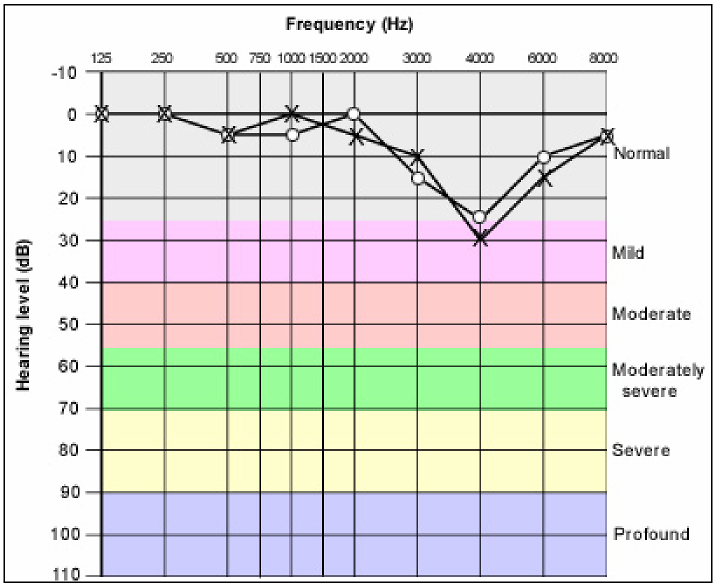
Individuals who sustain NIHL commonly are also affected by tinnitus. Tinnitus is described as constant or intermittent ringing, chirping, clicking, buzzing, beeping, and roaring as well as any abnormal sound heard by an individual (Berger, 2000). Current research does not show any medicinal cure for tinnitus; however, if it becomes handicapping for the individual, treatment regimens are available. Tinnitus retraining therapy, tinnitus maskers, and/or hearing aids are all effective treatments. Reduction in caffeine and nicotine are also effective for some individuals (Jastreboff, 2000).

Paracusis occurs when "…the pitch of tones near a region of impaired sensitivity due to noise is shifted; that is, a tone is heard, but one having an inappropriate pitch" (Ward et al, 2000). Since this can not be objectively measured, it is not known how much this may contribute to speech/sound intelligibility. However, it is a logical assumption that paracusis can adversely affect speech intelligibility.

NIHL can also result is what is known as a "noise notch." The initial loss typically manifests itself at or around 4000 Hz, while frequencies above and below 4000 Hz remain unaffected (assuming there are no other factors other than noise exposure). Depending on the severity, this "noise notch" can sometimes lead to speech misperception. Refer to **Figure 1** for a representation of a "noise notch,"—one that portrays an individual with virtually normal hearing, but still possessing a slight hearing loss due to hazardous noise exposure.

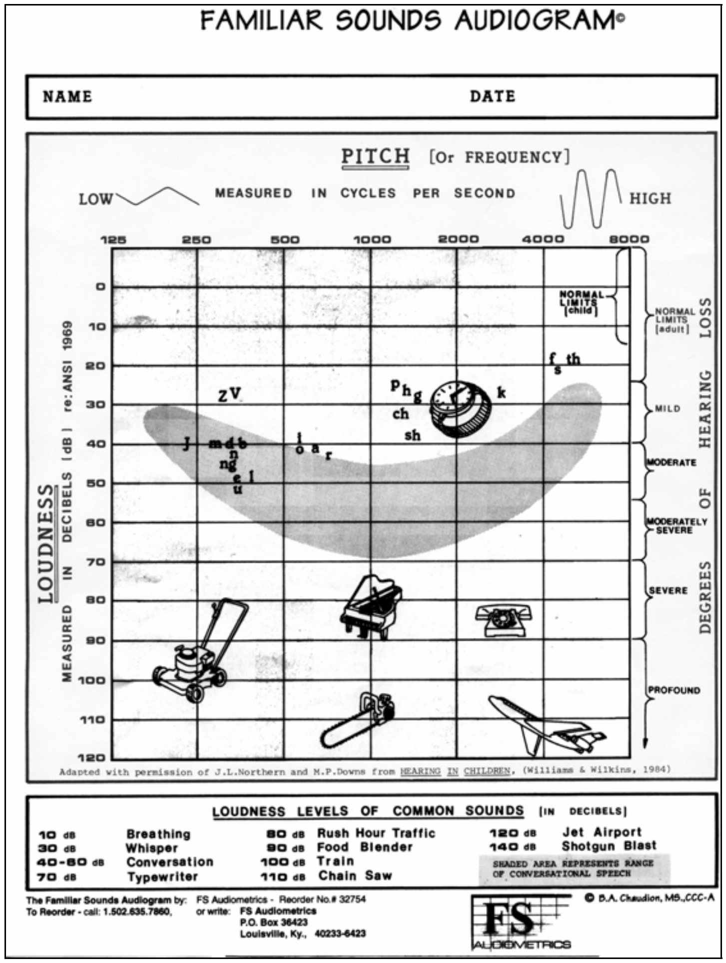
Figure 1: Example of a mild "noise-notch"

(Retrieved April 1, 2006, from http://www.aafp.org)



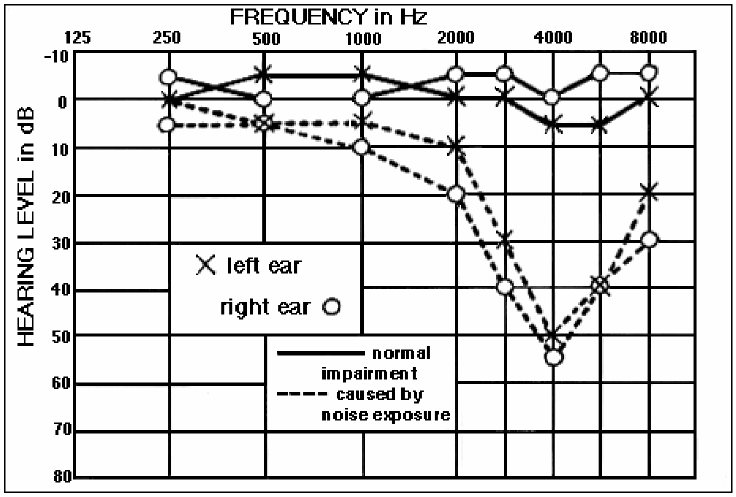
As seen in **Figure 1**, the "noise notch" occurs in the high frequency region (4000 Hz). Sounds located in this area are responsible for the speech clarity. Typically, individuals with a high frequency hearing loss report they can hear speech, but often fail to understand what is being said. This occurs because while individuals with high frequency sensorineural hearing loss can still perceive volume from better low frequency thresholds, they fail to distinguish between consonant sounds (Note **Figure 2**). Individuals with high frequency sensorineural hearing loss commonly report communication breakdowns when in noisy environments, because the individual has better low frequency hearing and noise is low frequency energy. He/she also has a high frequency hearing loss thereby hindering speech intelligibility.

Figure 2: Familiar Sounds Audiogram



Finally, individuals exposed to hazardous noise can experience temporary hearing loss. However, if an individual is exposed to hazardous noise over a long duration, it can affect thresholds permanently. While this permanent loss initially affects high frequencies, it can increase in severity and affect the mid and low frequencies as well. **Figure 3** demonstrates an audiogram representing the difference between normal hearing and the typical threshold configuration that is characteristic of NIHL. Note that the NIHL has not yet affected the low frequencies; however, the individual has sustained a moderately-severe high frequency sensorineural hearing loss.

Figure 3: Normal vs. NIHL Configurations



As stated, NIHL can cause nonauditory symptoms within an individual. Noise exposure can impact sleep and task performance, thereby affecting productivity levels. Moreover, lack of speech clarity caused by NIHL can evoke irritation and even rage within the struggling individual.

Finally, NIHL can be a detriment to the physiological systems of the human body. This includes "…increased heart rate, blood pressure, catecholamines, adrenalin secretion, vasoconstriction of the extremities, and dilation of the pupil of the eye…severe exposure produce or augment the stress reaction of the body and perhaps have an effect on the immune system…" (Ward et al, 2000).

Noise Standards

The National Institute for Occupational Safety and Health (NIOSH) defines hazardous noise as "any sound for which any combination of frequency, intensity, or duration is capable of causing permanent hearing loss in a specified population" (Retrieved April 1, 2006, from http://www.cdc.gov/niosh). The Occupational Safety and Health Administration (OSHA) commission states that there are approximately 30 million people exposed to hazardous levels of noise that can result in auditory damage (Retrieved April 6, 2006, from http://www.osha.gov). OSHA measures exposure in terms of the dosage, which is a percentage of allowable daily exposure. OSHA standards for a 100% dose are equal to an exposure level of 90 dB(A) for an 8-hour period of time. In other words, OSHA considers NIHL possible if the noise equals or exceeds 90 dB(A) and the individual is exposed continuously at this level for 8 hours. The general rule for permissible duration and intensity of noise exposure is that the intensity of exposure decreases by 5 dB for every doubling of the distance (OSHA, 1983). For example, if the exposure duration is 2 hours and the permissible intensity is 100 dB and the duration is increased to 4 hours (doubling the distance), the permissible level of exposure is 95 dB (decreases by 5 dB). These values are below in **Table 1**.

For the purpose of this pilot study, OSHA standards will be used to verify if output levels of dental handpieces are hazardous or not to the auditory system. The collected data will be compared with the information noted in **Table 1**.

Table 1: Permissible Noise Exposure Levels (OSHA, 1983)

Duration per day, hours	Sound level dB(A) slow response
8	90
6	92
4	95
3	97
2	100
1 1/2	102
1	105
1/2	110
1/4 or less	115

Currently, OSHA states the occupations that exceed permissible noise exposure levels include carpentry, plumbing, mining, agriculture, construction, manufacturing and utilities, transportation, and military. The Food and Drug Administration (FDA) mandates hearing protection for individuals in these professions. The FDA also mandates that these individuals can only be exposed to hazardous noise levels for a specified duration. This allows the auditory system within these individuals to recover naturally if any temporary threshold shift has occurred thereby preventing permanent hearing loss.

Research

Unlike industrial workers who are covered by occupational noise regulations, medical professionals are not regulated by any governmental agency. Though the FDA has not imposed any noise regulations, published studies reviewed below show that certain medical professionals are exposed to hazardous levels of noise in the workplace.

Orthopedic surgeons are exposed to hazardous levels of noise emitted from high-powered tools such as bone saws and high-powered suctions. According to Ullah et al (2004) the levels emitted from these instruments range from 73.1-119.6 dB SPL. The authors concluded that these levels could indeed cause a temporary and/or permanent threshold shift. Willett (1991) measured orthopedic surgical instruments and found they produced intensity levels of 90-100 dB SPL at the surgeon's ear. Willett (1991) administered pure tone hearing tests to 22 orthopedic personnel. After adjusting for age-related loss (presbycusis), 11 of the 22 personnel had a range of hearing loss at 6000 Hz of 12.3-15.9 dB SPL. Willett (1991) concluded that this peak loss located at 6000 Hz was consistent with the characteristics seen with NIHL. The author also concluded that use of specified orthopedic instruments could cause hearing loss.

Holmes et al (1996) also measured the output intensities of orthopedic surgical instruments. The average range measured was 95 – 106 dB(A). Investigators administered audiometric evaluations on 6 orthopedic personnel to determine if NIHL configurations were present. For 2 of the 6 personnel, audiometric results indicated a mild-moderate sensorineural hearing loss with a notch at 3 – 6 kHz. These results suggested a cause-effect relationship between the use of high-powered surgical instruments and resultant hearing loss.

Surgeons who specialize in extracorporeal shock wave lithotripsy may also be at risk for NIHL. Lusk et al (1987) measured impulses at 112 dB SPL from a surgical handpiece used during upper urinary tract surgery. The handpiece measured is called the Dornier system GmbH lithotripter, which produces extracorporeal generated shock waves that break down urinary tract stones. The shock wave is then followed by intense ambient noise. Although all surgical personnel were exposed to intense levels emitted by this handpiece, it was not as intense as the exposure experienced by the patient. The exposure amount was less intense for surgical personnel than the patient, but the duration was longer due to performing multiple procedures during the day. Lusk et al (1987) concluded that the emission produced by the lithotripter could result in NIHL based on the combination of intensity and duration. The authors recommended hearing protection for patients and operating personnel in order to protect against NIHL.

In a similar study, Teigland et al (1986) assessed three commercially available ultrasonic lithotripters used for upper urinary tract surgeries in various clinical settings. In all settings measured, the output levels were measured at 103 dB for all three instruments. The frequencies spectrum emitted from these instruments ranged from 200-10000 Hz, but was concentrated in the 3000 Hz region. The investigators concluded that the combined frequency and intensity emissions from the lithotripters could cause NIHL.

Not only are surgeons of multiple specialties exposed to levels of noise that can cause hearing loss, but dental professionals are as well. Studies published as early as 1959 suggested that use of high-speed ball-bearing turbines in dental practices can cause hearing loss. High-speed dental turbines were invented in 1949 (Terranova, 1967). Manufacturers and researchers found that high-speed turbines were prone to fewer accidents than the low-speed handpieces because they produced less torque. In 1954, manufacturers began production of these high-speed handpieces for use in dental practices.

In 1955, a high-speed belt-driven handpiece was manufactured that could perform at speeds up to 200,000 rpm, where previous handpieces could only attain speeds up to 30,000 rpm due to mechanical failure. In 1956, air turbines were manufactured and researchers reported that the best performance measured at 200,000 rpm and above with an air pressure of 30 psi. As the dental practice evolved into the everyday use of high-speed air-powered handpieces, conflicting results have been reported as to whether the noise exposure is actually hazardous or not to the auditory system.

Mittelman (1959) was one of the first dentists to suggest that the use of high-speed ball-bearing handpieces may be hazardous to the auditory system. Although he found empirical data levels inconclusive, he found enough evidence to recommend general preventative measures, including hearing protection during handpiece use.

As stated above, the hazardous nature of noise depends on three factors. These factors include intensity, frequency, and duration. Intensity is one factor that many researchers have assessed. Cantwell et al (1960) obtained noise measurements from two models of dental handpieces called the Ritter R-Borden Airotor and the Page-Chayes. These output levels were obtained in a small operatory room at the University of Oregon Dental School. The output intensity levels ranged from 80 dB-84 dB for the Ritter R-Borden Airotor. The maximum output levels for the Page-Chayes were measured 70-75 dB. Even if these handpieces were used continuously for an 8-hour period of time, the authors concluded that these levels cannot be considered hazardous to the dentist's/patient's auditory system. This coincides with the output levels for both the OSHA and NIOSH standards.

Two years later, Hopp (1962) conducted a study assessing 64 sophomore dental students at the University of California Dental School. Each subject was interviewed to determine history of hearing loss, otitis media, tinnitus, and noise exposure. Extensive histories were noted before audiometric testing began. For a six month period, each student self-reported the date, time, and length of exposure when using different handpieces. The investigators also quantified the distances the students were from the sound source in hand, as well as measured the distance from other turbines used within the clinic. Six months later, the students were re-examined and asked about any ensuing hearing problems that occurred in the last six months. The researchers also obtained threshold measures in order to note any hearing loss in comparison to the baseline audiogram they performed six months earlier. The investigators noted that 12 students had threshold shifts greater than 10dB at 2000, 4000, or 8000 Hz and 26 students had better threshold values of 10 dB or more at 2000, 4000, or 8000 Hz. The author concluded that with minimal use of air-turbine handpieces, students did not have acoustic trauma that could be considered statistically significant.

Terranova (1967) continued the research on high-speed handpieces; however, he concentrated on the amount of sound emitted from the ultra high-speed equipment in correlation with duration of use. He found that output from such instruments ranged from 74-104 dB. Terranova concluded that these levels could be considered hazardous to the auditory system, but suggested that it depended on the amount of time the dentists is exposed daily.

Ward et al (1969) attempted to quantify the acoustic hazards of dental handpieces due to reported allegations that handpiece use could result in hearing loss. At the 85th Annual Minnesota State Dental Association Convention, the investigators performed hearing threshold measures for 34 dentists. When cross-sectional as well as longitudinal comparisons were made, the researchers found that high-speed handpiece noise did not produce more than 5-10 dB hearing loss at 6 kHz. Although they noted slight hearing loss due to handpiece use, it was minimal in comparison to the thresholds measures of those exposed to gunfire without hearing protection. Although threshold shifts were minimal from handpiece use, the authors stated that it could not be claimed completely negligible.

Not only is intensity important in assessing the hazardous nature of noise, the spectral components of the output is also of great importance. Terranova (1967) noted that the ear is most vulnerable to frequencies ranging from 2.5-6 kHz, which is the range of most air-driven handpieces. Cantwell et al (1960) found the average output of dental handpieces was greatest in the 4800-9600 Hz octave band for two models of dental handpieces. Barek et al (1999) measured the spectrum of sounds emitted from three handpieces. The frequencies emitted ranged from 0-70 kHz. The peaks included 5.6 kHz, 20.1 kHz, 35.7 kHz, and 46.5 kHz. It is important to note that the range of human hearing is 20-20 kHz, so the output levels of 20.1 kHz, 35.7 kHz, and 46.5 kHz are inaudible. Barek et al (1999) also measured amplitude levels up to 115 dB SPL for selected handpieces. Although the intensity levels could be considered hazardous, the authors reported that more research was needed to determine if the amount of hearing loss resulting from handpiece use was based on the intensity of the output alone or a combination of intensity and frequency.

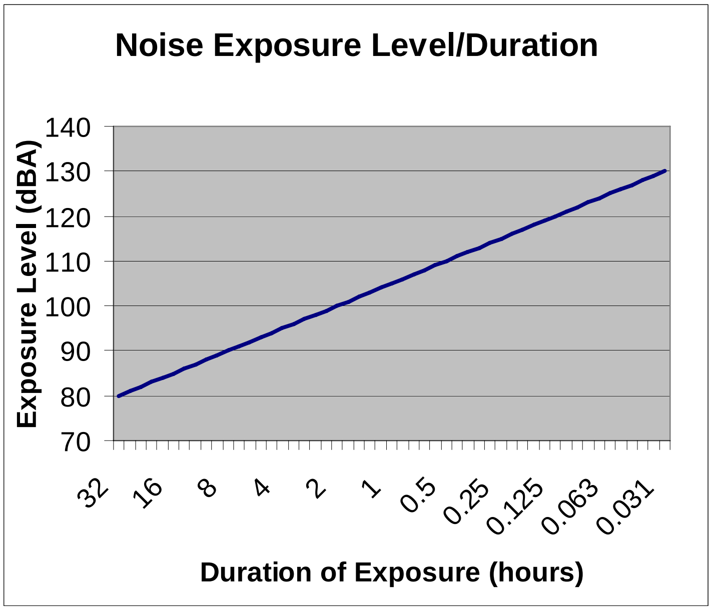
Altinoz et al (2001) quantified the frequency output of five high-speed dental turbines under eight different working conditions. Each turbine was also tested with and without the use of different burs on an amalgam block, composite block, and occlusal surface of an extracted molar. The investigators measured 30 cm from the source and the average frequency output was 6860 Hz. No significant differences were found among turbines indicating that all emit frequency levels that could potentially cause hearing loss. Schubert et al (1963) found the frequencies components that constitute handpiece emission ranged from 5000-10,000 Hz.

Another commonly used dental handpiece is the ultrasonic scaler, which Moller et al (1976) measured. Ultrasonic scaling is regarded as an imperative procedure in periodontal therapy. These instruments are used to irrigate areas under the gingival line in order to treat patients with periodontal disease. Due to their high frequency nature (25-42 kHz), the study assessed output levels to determine if they could be considered hazardous to the auditory system. 20 healthy dental students ages 22-36 were exposed to ultrasonic scaling on their maxillary teeth for 5 minutes. Researchers performed pure tone audiograms on each student both pre- and post-exposure. Temporary threshold shifts were found for 8 individuals. These shifts ranged from 10-20 dB at 8 kHz. 3 subjects reported tinnitus lasting 20-30 minutes following exposure. No permanent thresholds shifts were found.

Duration is also an important factor to determine if output intensity and/or frequency can cause hearing loss. The amount of time that a dentist continuously operates a handpiece depends on the type of procedure performed as well as individual preference and/or need. Schubert et al (1963), Cantwell et al (1965), and Peyton (1974) reported that dentists on an average operate handpieces continuously for 12 minutes per 8-hour day. In other words, the dentist actually uses the handpiece for short periods of time all of which equate to 12 minutes in an 8-hour period of time. Kilpatrick (1981) and Hendler et al (1984) estimated based on procedure and individual preference that the continuous exposure time ranged from 15-45 minutes based on an 8-hour day.

Regardless if the research proves that dental handpieces are hazardous or not to the auditory system, most authors suggest preventative measures that dental professionals should employ. The earliest preventative measures were reported by Mittelman (1959) who recommended hearing protection of which included saturating a cotton ball in olive oil and inserting into the ear canal. This would reduce the dentist's exposure by attenuating the output of the handpiece as it travels through the auditory system. Kessler et al (1961) and Terranova (1967) suggested that dentists have regular audiometric testing, wear hearing protection, as well as reduce ambient noise in the operatories. Noise and reverberation can be reduced with the addition of acoustical ceiling tiles, carpeting the floor, and having wall coverings to absorb reverberant emissions. Terranova (1967) also recommended that dentists have short ½ minute periods of drilling and several minute breaks in between usage. Schubert et al (1963) recommended that dentists concerned about their particular handpiece output as well as average daily use, should have noise measurement obtained by a competent acoustician and then analyzed as to the maximum safe exposure levels based on daily usage. **Figure 4** represents maximum safe exposure levels based on daily use. This data is based on OSHA standards (OSHA, 1983).

Figure 4: Maximum Safe Exposure Levels



Sheldon et al (1984) reported that several studies found a significant correlation between noise exposure from high-speed handpieces and resultant hearing loss. The investigators measured the output of handpieces at levels up to 90 dB depending on the model and age of handpiece. After collecting the data, they suggested a hearing conservation program including annual audiometric evaluations, use of hearing protection, maintenance of handpieces to include frequent lubrication, and reducing ambient noise in the operatories.

The Council on Dental Materials and Devices of the American Dental Association (1974) recognized the abundance of literature reporting the hazardous nature of dental handpieces. The council provided a hearing conservation program that included preventative measures to minimize the risk to dentists including optimal maintenance of rotary equipment, reduction of ambient noise levels in the operatories, and the use of hearing protection. The Council also recommended a baseline audiometric evaluation to document initial hearing threshold levels. Annual audiometric evaluations as well as annual otologic examinations were recommended to monitor the status of hearing as well as document any hearing loss.

Skurr et al (1970) began a prospective study in 1967 to assess the handpiece controversy. The investigators performed audiometric evaluations on 56 third-year dental students and 50 control medical students matched with similar audiograms. In a two year period of time, the dental students were exposed to 100-200 hours of high-speed handpiece noise. Skurr et al also noted that not only did students have exposure to handpiece noise, but also were exposed to gunfire and other noisy hobbies. Of the 32 subjects tested in 1969, 13 had retained normal threshold measures and 12 students had no other exposure than handpieces. Of the 19 subjects with significant threshold changes since baseline measurements, 5 were exposed to high-speed handpiece noise alone and the remaining 14 had previous accounts of hearing loss. Results indicated that although high-speed handpiece noise might cause hearing loss, it is more hazardous to those with previous hearing loss.

Kilpatrick (1981) stated that most hearing loss in dentists is due to the aging processes and not by handpieces alone. Presbycusis, hearing loss due to aging, manifests itself in a similar high frequency sensorineural hearing loss as NIHL does. With presbycusis however, the loss gradually progresses in nature and typically does not have a “notch” configuration. The loss begins in the high frequencies and can progress to mid and low frequencies through time. The loss is also symmetrical, which is not always so with NIHL.

Kilpatrick assessed 25 handpieces and found output levels ranging from 69-92 dB SPL. Although the original hypothesis was that *most* hearing loss was not caused by the handpiece, the author concluded that these instruments can be regarded as *contributing* to hearing loss. To decrease the amount of noise exposed, dentists were urged to keep a distance of 14 inches or more from the output source. As the dentist increases the distance between his ears and the handpiece, the output level is attenuated as it reaches the dentist.

PURPOSE

The research reviewed above indicates there is substantial controversy as to whether the use of dental handpieces cause NIHL. Not only are there conflicting results, but also many of these studies have failed to provide sufficient data on multiple handpieces and their effects on all dental professionals. These include dentists, as well as dental hygienists, and dental assistants. There is also minimal research describing the sound output of newer handpieces used in dental practices. Due to lack of sufficient and recent data, this study was two-fold: Experiment 1 reports the results of a survey of dentists in the St. Louis area and Experiments 2 reports the output data of selected dental handpieces.

The goal of Experiment 1 was to survey dentists within the St. Louis metropolitan area to assess the subjective opinions of some commonly used handpieces. The survey also assessed the subjective views of these dentists as to which handpiece(s) were the loudest as well as their personal background of noise exposure and use of hearing protection.

The goal of Experiment 2 was to quantify the noise output of some commonly used handpieces in the dental office. These results were then used to estimate daily exposures and determine the risk of producing NIHL for dental professional. The investigators measured handpieces at three distances including 6”, 12”, and 18”. These distances were chosen to simulate exposures distances during typical working conditions. The different distances accounted for personal preference distances of the dentist and dental hygienist (6” and 12”) as well the distance for microscope usage and dental assistant distance (18”). The handpieces were measured at the three distances while free running (without resistance) as well as modifying different materials. These materials included amalgam, gold, non-precious metal, dentition from an extracted molar, composite, and porcelain. The purpose of using different materials was to see if there were differences in output between materials. These results were compared to the free running output of each handpiece. Exposures were calculated on the basis of sound pressure level and duration of use data (collected from survey) to assess potential risk.

Experiment 1: Survey of handpiece use by dentists and dental professionals

Purpose

The first purpose of the dental survey was to determine which handpieces are commonly used in dental offices in the St. Louis area. Surveying several offices accounted for dentists within specialties, such as endodonics and pedodonics, which require different handpieces not often used by general dentists. This also allowed the investigators to account for the use of newer instruments across several offices.

The survey also assessed daily microscope use. This information allowed the investigators to take into account the increased distance (due to microscope use) between the handpiece emissions and the operator's ear.

The second purpose of the survey was to ascertain the subjective opinions of the dentists as to which handpieces (if any) seemed hazardous to hearing. It was important to assess if the subjective opinion was the sound emissions were considered "hazardous" or merely "noisy." The term "noisy" is used to describe a sound that is bothersome or annoying, while "hazardous" describes a sound that is harmful to the auditory system (Kryter, 1985).

The investigators also posed questions about possible symptoms that the dental professional might experience after use of certain handpieces. These symptoms might alert the investigators to possible temporary threshold shifts or permanent thresholds shifts experienced by the operator.

Finally, the survey assessed history of noise exposure as well as use of hearing protection. These responses were compared to responses about the hazardous nature of the handpieces. Those who report that a handpiece causes hearing loss might in fact have previous noise exposure. The cause of hearing loss might be due to an outside event as opposed to occupational noise exposure.

Hearing loss also results in a decreased dynamic range (range between threshold and uncomfortable loudness level). This limited dynamic range results in what is known as recruitment. This term is defined as an abnormal growth in loudness. In other words, the individual with hearing loss perceives loud sounds as excessively loud and the growth from threshold to uncomfortable loudness is quicker than one with normal hearing. This can result in a hypersensitive perception of loud sounds

The dental professional might report that the handpiece emissions are hazardous because of this hypersensitive sound perception. On the other hand, those who do not report the handpieces are hazardous might have hearing loss caused by a previous exposure and are less sensitive to the noise emitted from instrument. In other words, noise seems less intense due to hearing loss. All subjective reports were then compared to the measured output levels of these instruments (Experiment 2) in order to conclude if a correlation existed between the subject response and quantitative data.

Methods and Materials

The investigators conducted a subjective assessment of dental professionals using a survey of 12 practicing dentists in the St. Louis metropolitan area. The dentists chosen were ones that the primary investigator had contact with prior to the investigation. All dentists agreed to complete the survey for study purposes before it was sent via email. Upon the dentist’s approval, the survey was sent and returned to the investigators. These surveys were returned nameless to protect the anonymity of the participating dentists.

This survey included 22 questions determining commonly used handpieces in dental offices today. The survey also included inquiries about procedures performed with the selected handpiece and duration of continuous use during the procedure. Questions were posed to assess the opinion as to if these instruments could cause hearing loss, symptoms that might accompany use of certain handpieces, exposure background, and current use of hearing protection. Questions from the survey are located in **Table 2**.

Table 2: Dental Survey

1.	Please indicate the handpieces that you and your staff use in your office.
2.	For each handpiece, please indicate the procedure(s) performed.
3.	Please estimate how many times weekly you perform each procedure.
4.	For each procedure, please indicate the amount of continuous use that you use each handpiece.
5.	For each procedure, please indicate who is within arms length of the noise source while the instrument is in use.
6.	Do you use microscopes in any of the procedures above?
7.	If so, what procedure(s)?
8.	Are there any dental handpieces that you feel might be more hazardous to your hearing based on your experience?
9.	If so, which handpiece(s) and why?
10.	Have you noticed any symptoms once you have finished working with a particular handpiece, such as fullness in the ears, ringing in the ears, and/or decreased ability to hear?
11.	If so, please indicate the handpiece(s) that have caused these symptoms and please describe in detail the symptom itself.
12.	Are there any other symptoms that you have experienced using certain handpieces?
13.	If so, please indicate the symptom as well as the handpiece used.
14.	Have you ever considered or would you consider wearing hearing protection while using certain handpieces if found hazardous to your hearing?
15.	Were you ever in the military?
16.	If so, what branch?
17.	Were you involved with heavy artillery firing, regular gunfire, or loud machinery of any kind?
18.	If so, did you wear hearing protection?
19.	Do you have any hobbies that might be dangerous to your hearing? (hunting, etc.)
20.	If so, what are your hobbies and how often do you partake in these activities?
21.	Do you consistently wear hearing protection during the hobbies stated in question 20?
22.	How often, if at all, do you get your hearing checked?

Results

Surveys were sent via email to 20 practicing dentists in the St. Louis area and 12 (60%) were returned completed to the investigators. Outcome analysis of the completed surveys indicated the most commonly used low and high-speed handpieces. Because the focus of this study was on high-speed handpieces, only these instruments were taken into consideration when reviewing the surveys. Handpieces included the Midwest, 647B KAVO High-Speed, Star, and Japanese Generic. The investigators measured the output emission levels of a selected number of handpieces as well as those reported in the survey.

Weekly minutes of continuous use ranged from 30-2841 minutes for the Midwest, 154-993 minutes for the Kavo, 25.5-330 minutes for the Star, and 270-703.5 for the Generic Japanese. Overall continuous use across handpieces ranged from 30-2841 minutes.

It was found that 42% (5/12) of dentists surveyed reported that handpieces used in the office were not perceived as noisy nor did most report symptoms associated with temporary threshold shifts or permanent threshold shifts. Results indicated most dental professionals who responded to the survey do not use microscopes during typical dental procedures. It was also found that 75% (9/12) reported a history of noise exposure outside the office, but only 3 of these dentists reported wearing hearing protection during the exposures. Many dentists (67%, (8/12)) reported that they would wear hearing protection if scientific research reported that dental handpieces were emitting levels that could cause hearing loss. The range of previous audiometric evaluations ranged from 1 year to never. Please note all original data from surveys are located in **Appendix A**.

Discussion

The results of the survey showed that most dentists do not use microscopes during dental procedures. It was noted from one dentist that more dental professionals as well as newly graduated dentists are using microscopes for a variety of procedures. These results might be because those surveyed might be long-time practicing dentists. It was important to know the prevalence of microscope use in order to include the distance of 18" when collecting emissions data. Although few reported using microscopes daily, the 18" distance was still included in the measurements of Experiment 2.

Half of dentists surveyed did not report that handpieces were hazardous/noisy nor indicated any symptoms after use. Dental handpieces might not emit levels that are hazardous to the auditory system. The sample size might have played a role in the response percentage if the sample size was not large enough to encompass more dental professionals who believe that handpieces might cause hearing loss. The sample size might also be too small to encompass those suffering from symptoms associated with NIHL. Those surveyed might be younger professionals in the field and do not have as the extent of exposure to handpieces as those do who are long-time practicing dentists. Previous auditory exposure including military, lawn mowers, leaf blowers, power tools, gun usage, etc. might also play a role in affecting the subjective assessment of output levels of dental handpieces.

Seventy-five percent of dentists surveyed (9/12) noted a history of noise exposure. Reports of exposure included military services (gunfire), hunting/skeet shooting, and use of power tools. It is interesting to note that only two dentists reported exposures such as those obtained during lawn maintenance. This maintenance includes lawn mowing, leaf blowing, and trimming equipment. It is a logical assumption that most of the surveyed dentists consider noise emissions from lawn equipment hazardous to the auditory system. This piece of data is significant when assessing the subjective opinion of dentists if handpieces are hazardous to hearing. If the dentist has hearing loss unrelated to dentistry, handpieces might not be perceived as “loud” or “harmful” because hearing sensitivity is decreased. On the other hand, if a dentist has hearing loss, he/she might be more sensitive to loud sounds due recruitment. Due to this disparity, subjective perception by the dentist does not constitute valid interpretation of loudness and noise of dental handpieces.

Half of dentists surveyed reported they do not wear hearing protection during hobbies for which auditory damage can occur. Some dentists reported that the reason was because the exposure occurred many years ago. For example, some reported that they did not use hearing protection in the military. Whether it was not offered or the individual did not use hearing protection is not known from this survey. Also, there was a report that a dentist did not use hearing protection during power tool usage because he could not converse with others. Many did not provide reasons why they did not use hearing protection during hobbies that might cause hearing loss, which the investigators concluded as lack of education or lack of compliance.

Also important to note is that most dentists would consider wearing hearing protection during handpiece use if instruments were proven hazardous to hearing. This is interesting to note because most reported they did not wear hearing protection during hobbies such as gun fire, power tools, etc. Research has shown that these hobbies are hazardous to hearing and now provide warnings for those taking part in these activities.

Further investigation is warranted in order to conclude if those surveyed do not wear hearing protection due to lack of education about the auditory system and hazardous noise or due to compliance issues. Because most dentists surveyed would wear hearing protection if research reported handpieces caused hearing loss, it is logical to assume that most do not wear hearing protection during hazardous hobbies due to lack of education and not due to compliance issues. It might also be due to the prevalence of conflicting research to date about dental handpieces.

Dentists surveyed reported a range of time from their previous audiometric evaluations between one year ago and never. 83% (10/12) of surveyed dentists had hearing evaluations performed more than five years ago. Because most have not had hearing tests in the last five years it is a logical assumption that this is the reason they do not believe handpieces cause hearing loss. If the dentist does not believe handpieces are hazardous to the auditory system and do not have symptoms, the individual is unlikely to seek out audiologic services to monitor the status of their hearing.

Experiment 2: Noise Measurements of Dental Handpieces

Purpose

The purpose of Experiment 2 was to determine if dental handpieces are hazardous to the auditory systems of dental professionals. This was performed by measuring the output levels of six selected high-speed handpieces. Output levels and survey results were then compared to not only assess the handpieces objectively, but also compare the results with the subjective perspective of dentists. Few published studies have been conducted by an audiologist or acoustician with an extensive background in sound, noise measurement, and data analysis. A background in sound and the human auditory system is important in order to correctly collect the data as well as thoroughly analyze and conclude if it is hazardous or not to the auditory system.

Research analyzing newer handpieces is also inadequate. This can be inferred because very few published studies have taken place after the year 2000. Older handpieces might not emit hazardous levels of output, but newer and more commonly used instruments could be harmful to the hearing of dental professionals. Most studies also did not take into account the output of handpieces modifying different materials such as composite, gold, non-precious metal, porcelain, tooth enamel, and amalgam. Interaction between the handpiece and a certain material might attenuate the output or increase the output. In the present study, output levels were measured on all handpieces modifying different materials used in the dental office.

Methods and Materials

The sound levels produced by six dental handpieces were determined at distances that represent normal operational distances. The names of these handpieces include the 647 Kavo High Speed, 635 Kavo Pedo, Japanese Generic Full Size, Japanese Generic Pedo, Titan Sonic Scaler, and the Piezo ProSelect. Each instrument was measured at distances including 6", 12", and 18". Measurements at these distances were representative of the output of the high-speed handpiece in relation to the operator's ear. The distance of 6" and 12" were representative of the area between the dentist/hygienist and the handpiece based on distance preference, while 18" was representative of the distance between the operator's ear and handpiece while using a microscope. This distance was also representative of the distance between the handpiece output and the dental assistant.

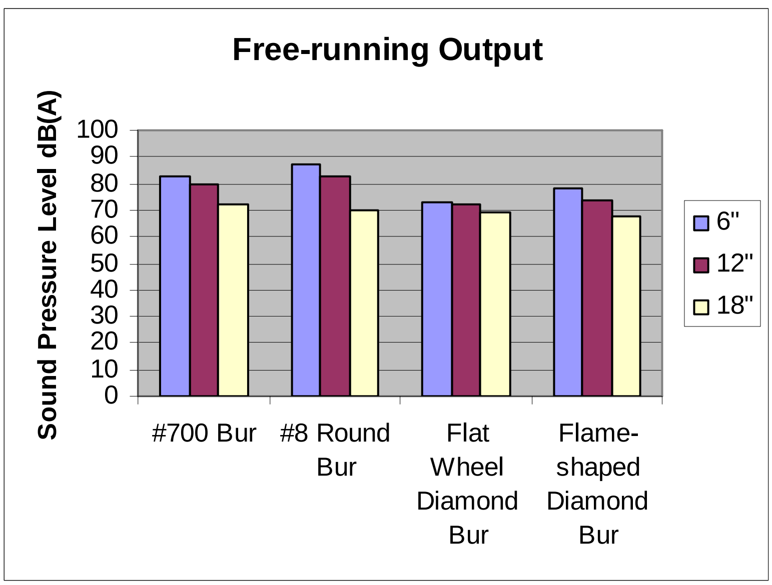
The output levels of six chosen handpieces were measured using a Spark 700 series dosimeter (Larson Davis Laboratories, Provo, UT). Dosimeter software (Blaze) was used to analyze the collected data. Information on the software can be found on the Larson Davis website (Retrieved April 5, 2006, from http://www.lardav.com).

All measurements were recorded in a selected dental office. The office had proper sound-reducing wall coverings, carpet, as well as acoustic ceiling tiles. Data was collected during after hours when no other dental procedures were occurring in any of the operatories. This was imperative when collecting the data to ensure that the intensity measurements were not affected by concomitant noise. Sound field measurements were obtained prior to making any handpiece measurements. These measurements were designed to assess the ambient noise present within the office operatory. The distances of 6", 12", and 18" were measured and marked on a cardboard surface. The microphone of the 700 series Larson Davis dosimeter was secured at one end of the measured cardboard.

During data collection, the handpiece was moved to each measured distance while the microphone remained in a stationary position.

Dental handpieces cannot run without a bur attached. To verify that the attached bur did not affect the overall output, the 647B Kavo High Speed was measured with four different burs attached. These burs included the #700 bur, #8 round bur, flat wheel diamond bur, and the flame-shaped diamond bur. The approximate output of these burs at each distance is seen in **Figure 5**.

Figure 5: Free-running Output with Four Burs



Because all the burs produced approximately the same output in SPL in the free-running condition, the investigators chose the #8 bur to measure the remaining instruments. It is important to note that this is a pilot study and the overall objective is not measuring bur type and subsequent output. The importance of this study was to assess overall output of commonly used handpieces while modifying different materials. For this reason, the bur selection was performed at random by the investigators and significance between burs was not calculated.

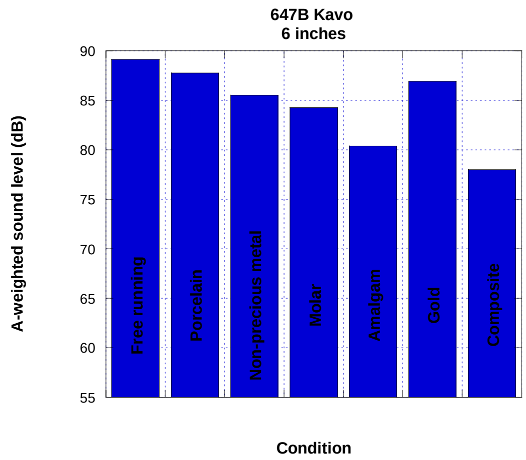
The handpieces were first run without resistance with the #8 round burr attached. Each handpiece was recorded at 6", 12", and 18". After the handpiece was measured at each distance with the #8 burr only, the handpiece was run at each distance while modifying a select material. The materials chosen covered the variety of materials used in a dental office including porcelain, non-precious metal, dentition of an extracted molar (general tooth material), amalgam, gold, and composite material. Each handpiece was measured at 6", 12", and 18" for approximately five seconds while modifying each material.

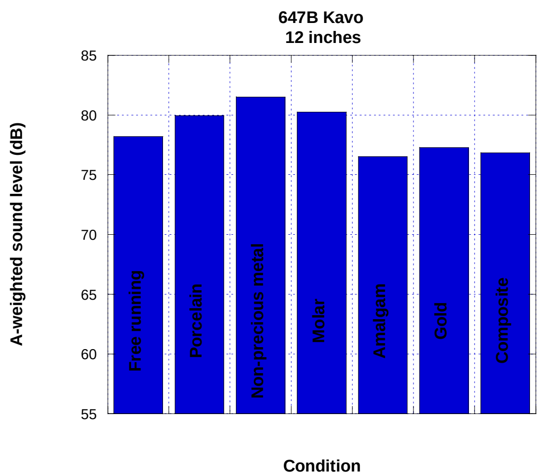
Results

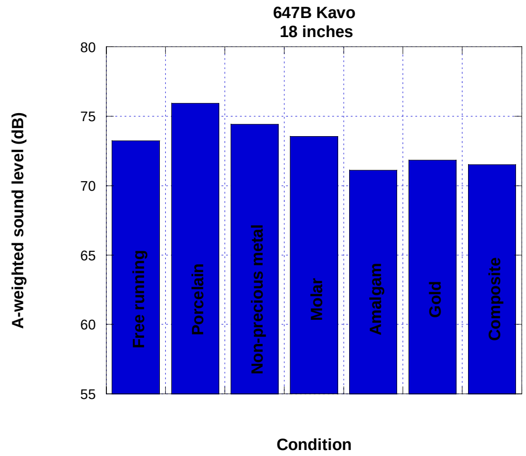
Raw data for the handpieces measured at all distances and in all conditions is located in **Appendix B**. Note that handpiece output was measured in decibels (dB) using an A-weighted scale.

The first handpiece measured was the Kavo 647B Full-size. This handpiece was measured for approximately five second intervals with the #8 round bur attached at the distances of 6”, 12” and 18”. These results were 88 dB(A), 78 dB(A), and 73 dB(A), respectively. Once the free-running measurements were obtained, the investigators measured the handpieces at same distances while modifying porcelain, non-precious metal, molar dentition, amalgam, gold, as well as composite. The output levels at each distance in the seven conditions are represented in **Figure 6**.

Figure 6: 647B Kavo High Speed (6", 12", 18")

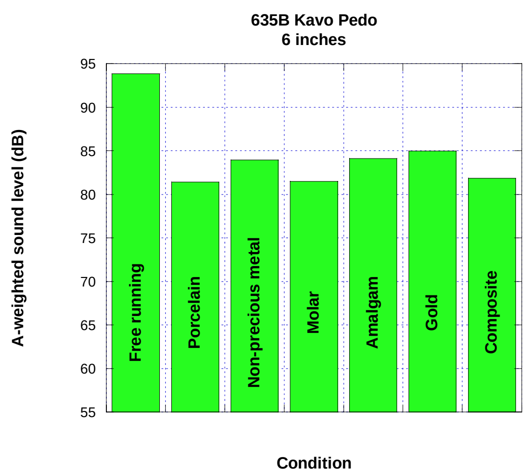


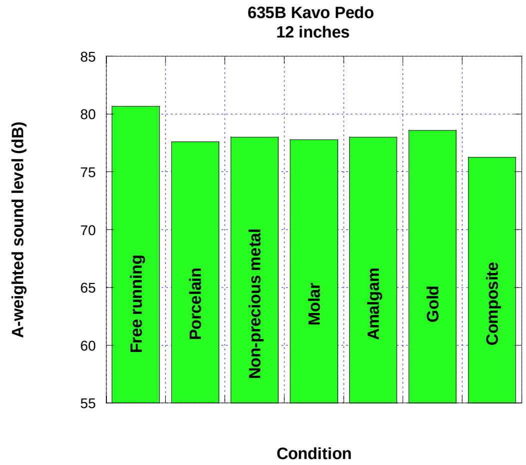


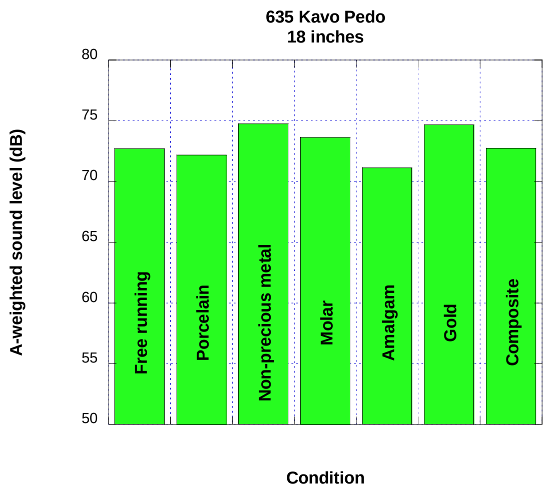


The 635B Kavo Pedo was measured while running without resistance at 6", 12", and 18" using a #8 bur. The output values were 93 dB(A), 80 dB(A), and 72 dB(A), respectively. The handpiece was the measured in the six conditions. These output levels are represented in **Figure 7**.

Figure 7: 635B Kavo Pedo (6", 12", 18")

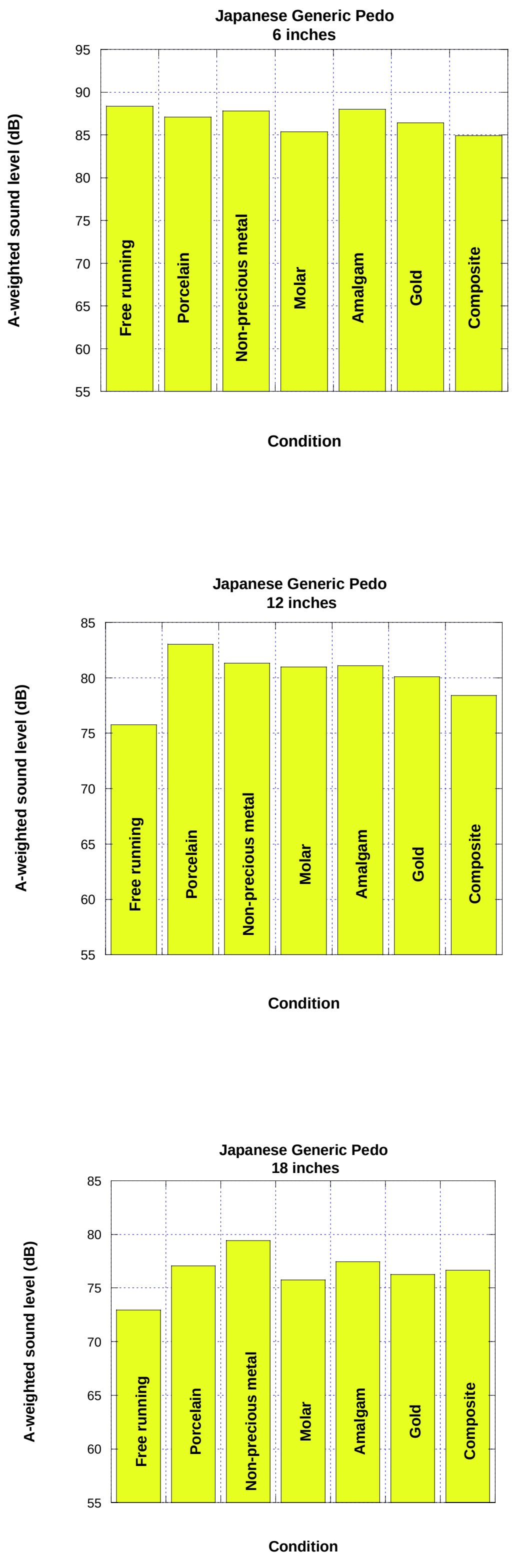






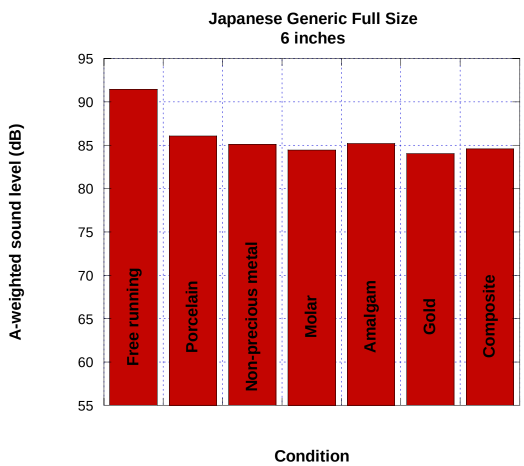
The Japanese Generic Pedo was then measured free-running at the specified distances of 6", 12", and 18". The outputs were 88 dB(A), 75 dB(A), and 69 dB(A) respectively. The following outputs of the 6 conditions in the three specified distances can be seen in **Figure 8**.

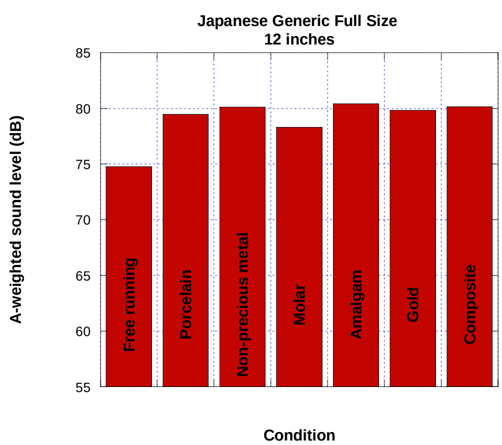
Figure 8: Japanese Generic Pedo (6”, 12”, 18”)

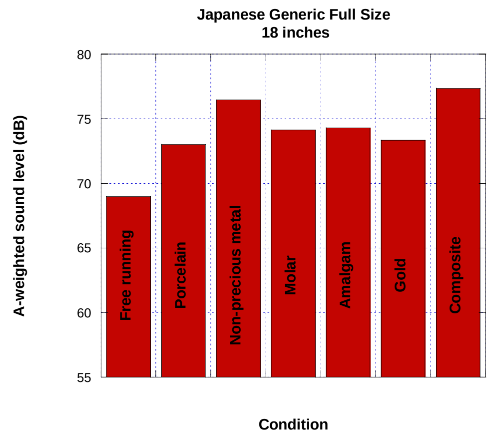


Finally, the Japanese Generic Full Size was measured free-running at 6", 12", and 18". The values were 89 dB(A), 75 dB(A), and 69 dB(A), respectively. The following outputs in **Figure 9** were found for the six conditions at the various distances.

Figure 9: Japanese Generic Full Size (6", 12", 18")







The two remaining handpieces were the ultrasonic scalers typically used typically used by most hygienists. These handpieces are not used for modification of materials such as porcelain, amalgam, gold, and composite. These instruments are typically used to remove hard deposits including calculus from the surfaces of teeth. Ultrasonic scalers are also used during periodontal procedures including debridement under the gingival tissues for the treatment of periodontal disease. The investigators measured two scalers including the Titan Sonic Scaler as well as the Piezo ProSelect.

The measurements were obtained in the same manner as the handpieces stated above, however, only two conditions (free-running, and molar dentition) were measured. The Titan Sonic Scaler was measured at 6", 12" and 18" and the outputs were 81 dB(A), 77 dB(A), and 72 dB(A) respectively. The outputs when in contact with molar dentition were 84 dB(A), 81 dB(A), and 79 dB(A). The outputs measured for the Piezo ProSelect free-running were 78 dB(A), 69 dB(A), and 69 dB(A). The outputs obtained when the instrument was in contact with molar dentition were 82 dB(A), 72 dB(A), and 70 dB(A) for the three specified distances. The raw data for the ultrasonic scalers at the three distances for the two conditions is located in **Appendix B**.

Discussion

The importance of Experiment 2 was to measure the output levels of selected handpieces in the seven conditions (free running, porcelain, non-precious metal, molar dentition, amalgam, gold, and composite) and assess if any could be hazardous to the hearing of dental professionals. The OSHA standard of 90 dB(A) exposure level for 8 hours was the standard to which all outputs were compared. Surveys as well as past research indicated that handpieces are run continuously for an average of 12-45 minutes based on an 8-hour day. (Schubert et al (1963), Cantwell et al (1965), Peyton (1974), Kilpatrick (1981) and Hendler et al (1984). The level a handpiece would have to emit for it to be considered hazardous for 12-45 minutes of use would have to range from approximately 105 dB(A) upwards to 140 dB(A). These values were found by using **Figure 4**. No handpiece measured during this study emitted a level this intense while either free-running or modifying a material, therefore the investigators concluded that use of these handpieces does not cause hearing loss.

When comparing across instruments, as assumed, intensity decreased as distance increased. As the distance increases between the handpiece and the operator, the sound waves have farther to travel thereby attenuating. This was seen with all handpieces measured and is demonstrated in **Figures 6-9**.

The investigators hypothesized that instruments in the free-running condition would emit greater output levels than when the handpiece was modifying any material.

They believed this would occur because when free running, the handpiece has no resistance thereby releasing the greatest amount of energy. This was not true in all cases. As seen in **Figure 7** free-running values were greater at the 6” and 12” measurements than when modifying a material. This was also the case with the Japanese Generic Pedo 6” and the Japanese Generic Full Size 6”. This can be seen in **Figure 8** and **9**. The researchers also hypothesized that there would be a difference in output when modifying different materials. This distance was thought to be due to the hardness of the material. A harder material would emit a great amount of noise while a softer would absorb some of the noise thereby emitting softer levels of output.

For the purpose of discussing the results, the researchers considered 12” to the standard to which the dental professional is away from the noise source. The 647B Kavo High Speed produced emission levels ranging from 76-81 dB(A). This handpiece produced approximately the same level of output in each condition measured. This instrument produced the greatest amount of noise when modifying non-precious metal. It is unknown whether this was due to the hardness of the material or otherwise. The researchers assumed that the handpiece would produce the greatest amount of noise during periods of free running due to lack of resistance, but this was not the case with the 647B Kavo. During the free-running condition, the 647B Kavo did not produce the highest nor the least level of emissions.

The 635B Kavo Pedo produced emission levels ranging from 76-80 dB(A). As with the 647B Kavo, the 635B Kavo Pedo produced approximately the same level of output in each condition. The range between materials was 76-78 dB(A). It is interesting to note that the 635B Kavo Pedo and the 647B Kavo produced almost the same range of outputs, however, the greatest output for the 635B Kavo Pedo was measured for the free-running condition. One would assume that since two handpieces are manufactured by the same company, the output levels, at least in the free-running condition, would be similar.

The Japanese Generic Pedo emitted levels ranging from 75-83 dB(A). The greatest emission was measured during modification of porcelain at 83 dB(A), which the researchers assumed due to the hardness of the material. It is interesting to note that the least amount of emissions was measured for the free-running condition, which was contrary to the investigators hypothesis.

The Japanese Full Size produced levels ranging from 75-80 dB(A). The investigators measured the greatest output during modification of non-precious metal. The least emissions were produced during the free-running condition, while the range between materials was 78-80 dB(A).

The scalers chosen, the Titan Sonic Scaler and the Piezo ProSelect, were both measured modifying molar dentition only. The outputs collected for both handpieces were 80 dB(A).

As stated above, the investigators hypothesized that there would be a difference of output levels based among materials being modified. This was not the case. When analyzing across handpieces, outputs were not consistent differences between materials. It is interesting to note that when modifying non-precious metal, all handpieces produced the greatest output or one of the higher outputs among conditions. This might have occurred because the non-precious metal is a harder material than the rest, thereby producing a greater output.

It is also interesting to note that there was also not a dramatic difference between instruments. Overall and by dental professional reports, the Japanese Generic Pedo created the highest amount of noise. It did produce the greatest output while modifying porcelain (83 dB(A)), but was not measurably greater than the other handpieces.

Because this is a pilot study, the significance between conditions within the same handpiece and across handpieces was not measured. Because the outputs varied based on condition, it is difficult to conclude why any condition produced greater output than the next. More research is needed as well as more measurements at each distance in order to better compare the conditions and outputs collected.

Conclusion

In conclusion, the six handpieces assessed (647B Kavo High Speed, 635B Kavo Pedo, Japanese Generic Pedo, Japanese Generic Full Size, Titan Sonic Scaler, and the Piezo ProSelect) did not emit hazardous levels of noise in any of the seven conditions (free-running, porcelain, non-precious metal, molar dentition, amalgam, gold, and composite). Even when taking into consideration the duration of time the handpiece is used, the emission is not significant enough to put dental professionals at-risk for NIHL. This data is based on the comparison to the OSHA standards which considers an individual at-risk if exposed to greater than 90 dB(A) for an 8-hour period.

Although the Japanese Generic Pedo measured higher emissions that the rest of the handpieces, whether or not the difference is significant is unknown. There were no overall differences measured between conditions within instruments. This is important for dental professionals to know, so they can assume that modifying a certain material does not emit a greater noise level than another material.

Due to the limited number of handpieces assessed, there might be other instruments used in the field that were not measured in this study. More research is needed to assess different handpieces not accounted for within this study. Results of subsequent research may conclude that there are instruments used in the profession that cause NIHL. Overall, more research is needed to confirm the results from this pilot study—that dental handpieces do not cause hearing loss.

The issue of frequency must also be taken into consideration. As stated in the beginning of this study, hazardous auditory output is affected by three stipulations including, intensity, duration, as well as frequency. Further research needs to be completed in regards to the frequency output of dental handpieces. The output measurements might yield certain frequencies that are more sensitive to hearing loss and might be part of the concern some dentists are expressing today.

It is a matter of concern that there are still practicing dentists who believe that the use of dental handpieces causes hearing loss. One reason for this report might be because there are professionals that are not using hearing protection during outside or non-professional activities that can be hazardous to their hearing. Activities that can cause hearing loss include gun hunting, use of firearms, wood-working equipment, lawn equipment, etc. These are the activities in which individuals need to protect their hearing by the use of ear plugs or ear muffs. Although the dental professional might indeed be losing their hearing from these activities, they might in error attribute it to the everyday use of dental handpieces. However, based on the data collected in this pilot study, dental professionals can assume that these handpieces do not emit a level of noise that can result in hearing loss.

Acknowledgments

I would like to sincerely thank all those whose help was imperative to the completion of this pilot study. Thank you Dr. Clark for the hours of time you put in to help mold me into a scientific writer and researcher. You taught me that writing is an art and the progression from start to finish requires endless patience, but the end makes you proud of the time and labor it took. Most of all, thank you to my family- my husband and parents whose daily encouragement and love I could not have lived without. You are my very heart and soul.

Appendix A

RAW DATA FOR DENTAL SURVEYS

	Handpieces	# Used weekly	Minutes Used	Microscope?	Hazardous?	Symptoms?	Noise Exposure?
Office 1	Kavo	18 (D)	45	No	Yes	No	Yes
	Generic Japanese	6 (D)	45	No	Generic		Hunting
	Star Titan Slow Speed	12 (D); 18 (H)	5 (D); 10 (H)	No	Japanese		Lawn mowing
	Star Titan Sonic Scalar	2 (H)	20	No	Pedo		
	Cavitron Scalar	1 (H)	20	No			
	Pro Select	16 (H)	45	No			
Office 2	Midwest	5 (D/DA)	5	No	No	No	None
		15 (D/DA)	5	No			
		5 (D/DA)	1	No			
		15 (D/DA)	2	No			
	A-Dec	5 (D/DA)	5	No			
		15 (D/DA)	5	No			
		5 (D/DA)	1	No			
		15 (D/DA)	2	No			
Office 3	Midwest	1 (D/DA)	30	No	All noisy	HL in right ear	USAF; no gunfire
		1 (D/DA)	30	No			
		3 (D/DA)	5-Jan	No			
		12 (D/DA)	10	No			
		2 (D/DA)	10	No			
		1 (D/DA)	10	No			
	Star	1 (D/DA)	30	No			
		1 (D/DA)	30	No			
		3 (D/DA)	10	No			
		12 (D/DA)	10	No			
		2 (D/DA)	10	No			
		1 (D/DA)	10	No			
	Borden Airator						
Office 4	Kavo	6 (D/DA)	5	Scopes	Yes	Mild HF HL	Flying 1x week
		15 (D/DA)	5		due to HF	and tinnitus.	Chain saw 1x/3mos
		1 (D/DA)	10		and vol.		
		1 (D/DA)	1		of noise.		
		1 (D/DA)	3				
		1 (D/DA)	2				
		0.5 (D/DA)	2				
		1 (D/DA)	5				
		1 (D/DA)	10				
		15 (D/DA)	1				
		1 (D/DA)	2				
	Star	65 (H)	5				
		1 (D/DA)	1				
		1 (D/DA)	1				
		1 (D/DA)	2				
		0.5 (D/DA)	2				
Office 5	Midwest	4 (H)		Yes, all	No	No	Military- gunfire
	Kavo	10 (D/DA)	30				Seasonally hunt
		2 (D/DA)	40				

		50 (D/DA)	10				
		4 (H)					
		7 (D)	10				
		2 (D/DA)	5				
		1 (D/DA)					
		2 (D/DA)	2				
		6					
			5				
		(D/DA)	3				
		(D/DA)	10				
Office 6	Midwest	10 (D/DA/H)	3-Jan	No	All seem	No	None
	Brasseler/NSK	12 (D/DA)	10		the same		
		3 (D/DA)	20				
		20 (D/DA)	3				
		2 (D/DA)	3				
		1 (D/DA)	10				
		2 (D/DA)	10				
		5 (D/DA)	2				
		DNA (D/DA)	2				
		3 (D/DA)	3				
		DNA (D/DA)	DNA				
		DNA (D/DA)	DNA				
		6 (D/DA)	3				
		1 (D/DA)	7				
		6 (D/DA)	3				
		6 (D/DA/H)	2				
Office 7	Midwest	3 (D/DA)	10	3.5 loops	n/a	Have HF loss	Hunt
		0.5 (D/DA)	20				Shoot trap
		5 (D/DA)	3				Lawn maintanence
		1 (D/DA)	10				Power tools
		1 (D/DA)	10				
		(D/DA)	2				
		0.2 (D/DA)	5				
		2 (D/DA)	5				
		0.2 (D/DA)	10				
		0.25 (D/DA)	25				
		0.25 (D/DA)	2				
	Star	5 (D/DA)	3				
		4 (D/DA)	2				
		(D/DA)	2				
		0.5 (D/DA)					
Office 8	Kavo	5 (D)	30	No	Japanese pedo	Fullness	Navy- gunfire
		0.5 (D)	60		handpiece-	ringing and	Hunt- rarely
		15 (D)	30		very loud	TTS	
		0.5 (D)	20			w/all	
		0.5 (D)	30			handpieces.	
		(D)	10				
		1 (D)	10				
		0.5 (D)	10				
		0.5 (D)	10				

		0.5 (D)	15				
		0.5 (D)	20				
		1 (D)					
	Star	30 (D/H)	5				
	Generic Japanese	5 (D)	30				
		0.5 (D)	60				
		15 (D)	30				
		0.5 (D)	20				
		0.5 (D)	30				
		(D)	10				
		1 (D)	10				
		0.5 (D)	10				
		0.5 (D)	10				
		0.5 (D)	15				
		0.5 (D)	20				
		1 (D)					
Office 9	Midwest	20 (D/DA)	15	No	No	No	Army- gunfire
		3 (D/DA)	25				Drums-
		120 (D/DA)	10				tinnitus
		120 (D/DA)	10				following use
		(D/DA)	2				
		5 (D/DA)	1				
		5 (D/DA)	1				
		4 (D/DA)	5				
		4 (D/DA)	2				
		2 (D/DA)	2				
		1 (D/DA)	8				
		2 (D/DA)	2				
		2 (D/DA)	5				
Office 10	Stryker Electronic	75 (D/DA)	5	No	No	No	USPHS Indian Hea none
Office 11	Kavo	6 (D/DA)	25	Yes ALL	Yes, Star 430-SWL-	No	Woodworking
		1 (D/DA)	45		noisier and		
		25 (D/DA)	6		high-pitched		
		20 (D/DA)	10				
		1 (D/DA)	20				
		1 (D/DA)	15				
		20 (D/DA)	8				
		4 (D)	5				
		8 (D/DA)	8				
		2 (D/DA)	10				
		1 (D/DA)	10				
		1 (D/DA)	10				
		1 (D/DA)	20				
		1 (D/DA)	35				
		6 (D)	2				
		4 (D)	4				
Office 12	Kavo High Speed	10 (D/DA)	10	No	Kavo	Loss of	No

		.5 (D/DA)	2			hearing in	
		.5 (D/DA)	10			left ear	
		2 (D/DA)	10				
		2 (D/DA)	10				
	Lares	10 (D/DA)	10				
		.5 (D/DA)	2				
		.5 (D/DA)	10				
		2 (D/DA)	10				
		2 (D/DA)	10				

Appendix B

RAW DATA FOR HANDPIECE OUTPUT

		1/12/2006		
DENTAL TURBINE	**Material Used**	**6"**	**12"**	**18"**
647B KAVO High Speed				
#700 Burr	none	83	80	72
#8 Round	none	88	78	73
Flat Wheel Diamond	none	73	72	69
Flame-shaped Diamond	none	78	74	68
635B KAVO Pedo				
#8 Round Free Run	none	93	80	72
#8 Round Free Run	none			
Japanese Generic Pedo				
#8 Round Free Run	none	88	75	72
Japanese Generic Full Size				
#8 Round Free Run	none	89	75	69
647B KAVO High Speed	Porcelain	85	78	75
	Non-precious metal	85	81	74
	Molar	84	78	73
	Amalgam	80	76	70
	Gold	87	77	70
	Composite	75	76	70
635B KAVO Pedo	Porcelain	81	77	72
	Non-precious metal	83	78	74
	Molar	81	77	72
	Amalgam	83	77	71
	Gold	84	78	73
	Composite	82	76	72
Japanese Generic Pedo	Porcelain	86	83	76
	Non-precious metal	87	81	77
	Molar	85	81	75
	Amalgam	87	81	76
	Gold	86	79	78
	Composite	83	77	76
Japanese Generic Full Size	Porcelain	86	79	72
	Non-precious metal	84	80	76
	Molar	84	78	73
	Amalgam	84	79	73
	Gold	84	78	72
	Composite	84	79	75

Titan Sonic Scaler	Free run	86	74	73
	Molar	88	80	76
Piezo ProSelect	Free run	78	69	69
	Molar	82	80	73

Appendix C

REFERENCES

REFERENCES

1. ACOEM (2002). ACOEM evidence-based statement: noise-induced hearing loss. Retrieved April 16, 2006, from http://www.acoem.org/guidelines/pdf/noise-induced-hearing-loss-10-02.pdf
2. Allen E, Rhoads R. (1963). Effects of high speed periodontal instruments on tooth surface. *J Periodont* 34:352-356.
3. Altinoz HC, Gokbudak R, Bayraktar A, Belli S. (2001). A pilot study of measurement of the frequency of sounds emitted by high-speed dental air turbines. *J Oral Sci* 43:189-192.
4. American Speech-Language Hearing Association. (1991). Combatting Noise in the '90s: A Nation Strategy for the United States. *ASHA* 1-90.
5. Bahannan S, El-Hamid A, Bahnassy A. (1993). Noise level of dental handpieces and laboratory engines. *J Prosthetic Dent* 70:356-360.
6. Barek S, Adam O, Motsch J. (1999). Large band spectral analysis and harmful risks of dental tubines. *Clin Oral Invest* 3:49-54.
7. Berger, E. (2000). Noise Control and Hearing Conservation: Why Do It? In: Berger E ed. *The Noise Manual*. Fairfax: American Industrial Hygiene Association, 1-18.
8. Cantwell K, Tunturi A, Manny V. (1960). Noise from high-speed dental handpieces. *JADA* 61:571-577.
9. Cantwell K, Tunturi A, Sorenson F. (1965) Noise levels of a newly designed handpiece. *J Pros Dent* 15:356-359.
10. Coles R, Hoare N. (1985). Noise-induced hearing loss and the dentist. *Br Dent J* 159:209-218.
11. Council on Dental Materials and Devices of the American Dental Association. (1974). Noise control in the dental operatory. *JADA* 89:1384-1385.
12. Forman-Franco B, Abramson A, Stein T. (1978). High-speed drill noise and hearing: audiometric survey of 70 dentists. *JADA* 97:479-481.
13. FS Audiometrics. *Familiar Sounds Audiogram*.
14. Gijbels F, Jacobs R, Princen K, Nackaerts O, Debruyne F. (2006). Potential occupational health problems for dentists in Flaunders, Belgium. *Clin Oral Invest* 10:8-16.
15. Hendler S, Miller M. (1984). "It Hertz" Audiologic concerns for the dentist. *NY J Dent* 54:211-213.
16. Hinze H, DeLeon C, Mitchell W. (1999). Dentists at high risk for hearing loss: protection with custom earplugs. *Gen Dent* 47:600-603.
17. Holmes G, Goodman K, Hang D, McCorvey V. (1996). Noise levels of orthopedic instruments and their potential health risks. *Orthopedics* 19:3-5
18. Hopp E. Acoustic Trauma in High-Speed Dental Drills. *Laryng* 1962;72:923-827.
19. Hyson J. (2002). The air turbine and hearing loss. *J Am Dent Assoc* 133:1639-1642.
20. Jastreboff, P. (2000). Tinnitus Habituation Therapy (THT) and Tinnitus Retraining Therapy (TRT). In Tyler R. ed. *Tinnitus Handbook*: San Diego: Singular Publishing Group, 357-376.

21. Kamal S. (1982). Orthopaedic theatres: A possible noise hazard? *J Laryngol Otol* 96:985-990.
22. Kessler, H. (1961). Noise problems in dentistry. *Oral Hygiene* 1:27-29.
23. Kessler, H. (1960). The dentist's hearing and ultra speed equipment. *Dent Survey* 36:1034-1036.
24. Kilpatrick H. (1981). Decibel rating of dental office sounds. *J Pros Dent* 45:175-178.
25. Kryter, K. (1985). Definitions of Noise and Noise Pollution. In: Kryter K ed. *The Effects of Noise on Man* Orlando: Academic Press, Inc, 1-3.
26. Love H. (2003). Noise exposure in the orthopaedic operating theatre: a significant health hazard. *ANZ J Surg* 73:836-838.
27. Lusk R, Tyler R. (1987). Hazardous sound levels produced by extracorporeal shock wave lithotripsy. *J Urol* 137:1113-1114.
28. Mittelman, J. (1959). The dental practitioner and hearing. *JADA* 58:158.
29. Moller P, Grevstad A, Kristoffersen T. (1976). Ultrasonic scaling of maxillary teeth causing tinnitus and temporary hearing shifts. *J Clin Periodontol* 3:123-127.
30. OSHA (1983). Department of labor occupational noise standard. CFR 29, 1910.95.
31. Peyton F. (1974). Status report on dental operating handpieces. *JADA* 89:1162-1170.
32. Ray C, Levinson R. (1992). Noise pollution in the operating room: a hazard to surgeons, personnel, and patients. *J Spinal Dis* 5:485-488.
33. Schubert E, Glorig A. (1963). Noise exposure from dental drills. *JADA* 66:751-757.
34. Sheldon N, Sokol H. (1984). Dental drill noise and hearing conservation. *NY State Dent J* 50:559-561.
35. Skurr B, Bulteau V. (1970). Dentists' hearing: the effect of high speed drill. *Aust Dent J* 1:259-260.
36. Sorrin S, Ewen S. (1965). Ultrasonics in periodontics. *NY State Dent J* 31:277-284.
37. Szymanska, J. (2000). Work-related noise hazards in the dental surgery. *Ann Agric Environ Med* 7:67-70.
38. Teigland C, Clayman R, Winfield H, Roeser R. (1986). Ultrasonic lithotripsy: the risk of hearing loss. *J Urol* 135:728-729.
39. Terranova P. (1967). Adverse conditions found in the use of ultra high-speed equipment. *NY State Dent J* 33:143-148.
40. Trenter S, Walmsley A. (2003). Ultrasonic dental scalar: associated hazards. *J Clin Periodontol* 30:95-101.
41. Ullah R, Baile N, Crowther S, Cullen J. (2004). Noise exposure in orthopaedic practice: potential health risk. *J Laryngol Otol* 118:413-416.
42. von Krammer, R. (1968). High speed equipment and dentists' health. *J Pros Dent* 19:46-50.
43. Ward W, Royster J, Royster L. (2000). Auditory and Nonauditory Effects of Noise. In: Berger E ed. *The Noise Manual*. Fairfax: American Industrial Hygiene Association, 123-147.

44. Ward W, Holmberg C. (1969). Effects of high-speed drill noise and gunfire on dentists' hearing. *J Am Dent Assoc* 79:1383-1387.
45. Willett K. (1991). Noise-induced hearing loss in orthopaedic staff. *J Bone Joint Surg* 73:113-115.
46. www.aafp.org
47. www.acoem.org
48. www.cdc.gov/niosh
49. www.lardav.com
50. www.osha.gov
51. Zubick H, Tolentino A, Boffa J. (1980). Hearing loss and the high speed dental handpiece. *AJPH* 70:633-635.